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2.	Patent application number *(The Patent Office will fill in this part)*	26 JUL 2002 0217297.1 — 26JUL02 E736167-1 D02866 P01/7700 0.00-0217297.1
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	CNH Belgium N.V. Leon Claeysstraat 3A B-8210 Zedelgem Belgium
	Patents ADP number *(if you know it)*	08399081001
	If the applicant is a corporate body, give the country/state of its incorporation	Belgium
4.	Title of the invention	METHODS OF OPTIMISING STOCHASTIC PROCESSING PARAMETERS IN CROP HARVESTING MACHINES
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	ERIC POTTER CLARKSON PARK VIEW HOUSE 58 THE ROPEWALK NOTTINGHAM NG1 5DD
	Patents ADP number *(if you know it)*	1305010

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

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11. I/We request the grant of a patent on the basis of this application.

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Date
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METHODS OF OPTIMISING STOCHASTIC PROCESSING PARAMETERS IN CROP HARVESTING MACHINES

This invention relates to methods of optimising stochastic processing parameters in crop harvesting machines such as but not limited to combine harvesters.

Combine harvesters and other harvesting machines have in recent years played a significant role in the development of so-called "precision farming" techniques.

"Precision farming" is a broad term that embraces practices such as:

- field yield mapping aimed at accurately mapping the crop-producing productivity of a field so that:
  - seeds and agrochemicals can be economically and correctly applied without over- and under-dosing the plants
  - harvesting and other agricultural machinery can be adjusted to take account of varying crop conditions from place to place in a field;

- modelling, of process conditions, within agricultural machines, and developing control philosophies aimed at:
  - improving machine efficiency or workrate;
  - reducing fuel consumption; and
  - improving the quality of work carried out by agricultural machines;

- providing alerts and reports of abnormal conditions in crops.

Sometimes the overall improvement in farming efficiency resulting from an

individual precision farming practice might be only a few percent; but cumulatively such efforts have dramatically improved productivity in mechanised farming over recent years.

The significance of harvesters, such as combine harvesters, to precision farming derives principally from the following factors:

(i) A harvester is able to assess the output of a farming operation for example in terms of crop yield. A field map of such data is invaluable in improving farming efficiency in future crop growing and harvesting seasons;

(ii) Harvesters are complicated machines that provide numerous sites for the location of transducers whose function is to gather data on the harvesting processes and the crops passing through the machine.

As noted, the combine harvester has been particularly useful in producing maps indicating the expected crop yield at different locations in a field. Farmers can use such maps (that are readily stored in digital form in a computer memory) to control in an accurate way the processes forming part of a crop growing season, so that the yield of the field is maximised.

Prior art techniques for yield mapping, however, are limited primarily because they concentrate on the quantity of the useable part of the crop that is conveyed to e.g. the clean grain tank in a combine harvester.

Although measurements of eg. the mass flowrate of clean grain to the clean grain tank may readily be compensated for some variables such as grain moisture content and grain type, some difficulties remain.

Significant among these is the fact that mass flowrate measurements of crop

yield generally take no account of crop losses arising from eg. incomplete or faulty threshing of ears in the threshing drum or another part of the harvester where grain separation occurs. Where the machine load exceeds the threshing, separation and/or cleaning capacity of the machine a portion of the harvested grain will be deposited on the ground behind the machine, together with the straw and the chaff.

Investigations by the inventors have revealed, for example, that the extent to which (or the ease with which) ears are threshed in the threshing drum of a combine harvester is strongly dependent on the feedrate of crop into the harvesting machine, when such factors as grain and straw moisture, crop variety and straw length are kept as constants. Thus for higher feedrates relatively less grain is separated in the first concave threshing drum section than in the case of low feedrates.

Consequently for such high feedrates a lesser proportion of the crop is therefore likely to reach the clean grain tank, with the result that a yield measurement taken at such a location may be inaccurate. Furthermore such a measurement takes no account of the extent to which grains become damaged or lost within the combine harvester.

In reality a great number of variables influences the extent to which the threshing and separating sections are able to separate grain from other plant matter such as chaff and straw. Such variables include, but are not limited to:

- the nature of the soil in which the crop grows;
- settings of various adjustable components of the harvesting machine, eg. the height of the header bar in a combine harvester, which directly influences the straw to grain ratio;
- the slope of the field in which the machine operates;

- the moisture content of the crop;
- the crop type;
- the forward speed of the harvesting machine;
- the presence of weed patches;
- the state (wear) of the machine elements;
- the type of installed machine elements, e.g. the type of rasp bars;

and so on.

According to a first aspect of the invention there is provided a method of substantially continuously optimising a stochastic parameter that characterises the instantaneously prevailing readiness with which a harvesting machine processes crop, including the step of recursively calculating the optimised parameter value in accordance with the following algorithm:

$$\vartheta(t) = f\left(\vartheta(t-1),\ldots,\vartheta(t-n_\vartheta),\varepsilon(t),\ldots,\varepsilon(t-n_\varepsilon),t\right) \qquad \text{- (A)}$$

wherein

$\vartheta(t)$ is the stochastic parameter value at time t; and

$\varepsilon(t)$ is an error prediction function.

Such a method is highly suited to the continuous optimisation of the highly stochastic parameter ϑ that, when applied to the threshing and separation process a combine harvester, may fairly be termed a "threshability" parameter, ie. an indication of the extent to which the harvesting machine is capable of threshing the crop at time *t*.

Such a parameter is useable in various ways, as discussed hereinbelow.

The method of the broad aspect of the invention can readily be carried out using a suitably programmed computer carried by or forming part of the

harvesting machine.

Preferably the algorithm (A) has the form :

$$\hat{\vartheta}(t)=\hat{\vartheta}(t-1)+\gamma(t)r^{-1}(t)\psi\left(t,\hat{\vartheta}(t-1)\right)\varepsilon\left(t,\hat{\vartheta}(t-1)\right)$$

wherein

$\gamma(t)$ is a gain term;

$r(t)$ is a scalar approximation of a Hessian $V''(\vartheta)$ in which V is indicative of the harvesting machine load; and

$\psi(t,\vartheta)=\dfrac{d\hat{y}(t,\vartheta)}{d\vartheta}$, in which $\hat{y}(t,\vartheta)$ is an estimation of a value indicative of the effectiveness of said harvesting machine processing said crop.

Preferably the algorithm (A) includes an estimation of $r(t)$ that is weighted to reduce the influence, on the optimised parameter values, of past measurements of crop feedrate.

This aspect of the method renders the parameter optimisation more realistic and robust for a wide range of working conditions.

According to a second aspect of the invention there is provided a method of operating a harvesting machine comprising the steps of:

(i) substantially continuously optimising a stochastic parameter that characterises the instantaneously prevailing readiness with which the harvesting machine processes crop;

(ii) substantially continuously adjusting a performance variable of the harvesting machine in dependence on the instantaneous, optimised value of the said parameter in order to optimise the load of the harvesting machine so as to keep a value indicative of the effectiveness of said harvesting machine below a predetermined value.

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The effectiveness value may comprise the losses of useable crop parts such as separation or cleaning sieve losses, or a proportion of damaged useable crop parts, e.g. broken grain kernels, or a proportion of unwanted material in the useable crop parts, e.g. chaff and straw and particles in the clean grain.

Optimising the machine load may comprise optimising the feedrate of crop into the harvesting machine, e.g. by adapting the travel speed of the harvesting machine.

Conveniently the step (ii) of adjusting a performance variable of the harvesting machine occurs in dependence on the output of an inverted form of a effectiveness estimation function:

$$\hat{y}(t,\vartheta) = \exp(\vartheta u(t)) - 1 \qquad \text{- (B)}$$

Herein *u(t)* may be the measured feedrate and $\hat{y}(t,\vartheta)$ the grain losses.

According to a third aspect of the invention there is provided a method of mapping one or more field lots for variations in a stochastic parameter that characterises the instantaneously prevailing readiness with which a harvesting machine processes crop, the method comprising the steps of:

(i) operating a harvesting machine to harvest crop in a said field lot;

(ii) simultaneously measuring the machine load and the machine effectiveness and determining the position of the machine in the field lot;

(iii) storing data indicative of the position of the harvesting machine at time *t*;

(iv) using the measured machine load and machine effectiveness data in an optimisation of the said parameter; and

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(v) mapping the optimised parameter values obtained from step (iii) so as to produce a parameter map of the field lot.

According to a fourth aspect of the invention there is provided a method of operating a harvesting machine comprising the steps of:

(i) substantially continuously optimising a stochastic parameter that characterises the instantaneously prevailing readiness with which the harvesting machine separates useable crop parts from other plant matter;

(ii) sending a display signal, that is indicative of the instantaneous parameter value, to a display device.

Preferably the display signal indicates an abnormal parameter value.

Preferably in each of the second, third and fourth aspects of the invention the optimisation step is in accordance with the first aspect of the invention. Thus the method of the first aspect of the invention is highly versatile in its application..

Conveniently in each of the 2nd to 4th aspects of the invention, when the parameter optimisation is according to the first aspect of the invention, the said selected part of the harvesting machine is selected from:

the separation section, e.g. the straw walkers or a rotary separator;
the sieve;
the return flow system; or
the cleaning section;
the grain elevator;

of a combine harvester.

The invention will now be described in more detail, by way of non-limiting example. In the following description reference is made to the

accompanying drawing figures in which:

Figure 1 is a schematic representation of the threshing, cleaning and straw walker sections of a combine harvester showing the possible locations for grain loss transducing devices;

Figure 2 is a graphical representation of the highly stochastic nature of a processability, in particular threshability parameter ϑ, by reference to field slope (gradient) values;

Figure 3 shows a practical realisation of the algorithm used in invention;

Figure 4 shows a graphical form the variability of the optimised parameter value from place to place in a field undergoing harvesting. The Figure 4 graph also includes, for comparison purposes, plots of parameter values calculated offline using a Least Squares technique also used to generate the plots of Figure 2; and

Figure 5 is a comparison between a parameter value map and the slope of the field to which it relates.

The terms "grain", "straw", and "tailings" are used principally throughout this specification for convenience and it should be understood that these terms are not intended to be limiting. Thus "grain" refers to that part of the crop which is threshed and separated from the discardable part of the crop material which is referred to as "straw". Incompletely threshed ears are referred to as "tailings". Also, the terms "forward", "rearward", "upper", "lower", "left", "right", etc. when used in connection with the combine harvester and/or components thereof, are determined with reference to the combine harvester in its normal operational condition and may refer either to the direction of forward operative travel of the combine harvester or to the direction of normal material flow through components thereof. These terms should not be construed as limiting.

Figure 1 shows the position of respective grain loss sensors 10, 11, 12 in the

separation (13), cleaning (14) and return flow (16) sections of a typical combine harvester. The illustrated separation section comprises a set of straw walkers 13, but the invention may also be used with harvesters comprising a rotary separator.

Any of the positions 10, 11, 12 may readily be used within the scope of the invention as locations for grain loss sensors. The following notes apply to the respective sensors:

10. Separation losses are generally measured by means of impact detectors. Impacts of kernels are separated from impacts of straw ends and counted each second. By this, a measure is found for the amount of separation losses. Since the distribution of free grain kernels along the depth of the straw layer varies in time, only a rough indication is normally obtained.

11. One similar impact sensor may be installed at the end of the cleaning section. Again only a rough measure is normally found for the sieve losses.

12. Tailings fall behind the lower sieve into the cross auger of the return flow system. An impeller is installed at the end of the fast rotating auger to spread the return flow. The sensor preferably operates measuring the phaseshift between a fixed impeller and a flexible one (EP-A-0 463 240). Higher material flows imply larger phase shifts.

In addition, the harvester preferably is equipped with precision farming tools to measure the actual cutting width, ground speed, mass flow, feedrate and within field position.

The outputs of such sensors may be employed in a prior art technique,

involving the use of an offline model, for optimising the threshability parameter ϑ.

The exponential function offers good opportunities to predict separation losses $\hat{y}(t,\vartheta)$ (T/h) based on an online measurement of feedrate *u(t)* (T/h) (Maertens *et al.*, 2002b; Schneider, 2000):

$$\hat{y}(t,\vartheta) = \exp(\vartheta u(t)) - 1 \tag{1}$$

Equation (1) ensures that no separation losses occurs for a zero feedrate and the feedrate-loss relation is fully determined by parameter θ. The time delay between the feedrate signal *u(t)* and *y(t)* is assumed to be fixed and an optimal fixed time shift (typically 11s) is installed as a compensation. For online measurements, separation losses and feedrate will be expressed in respectively impacts per second (#/s) and Volt (V). To optimise the parameter θ, following quadratic criterion $V(\vartheta)$ is proposed in function of prediction error $\varepsilon(t,\vartheta)$ (#/s):

$$V(\vartheta) = E\{0.5\varepsilon^2(t,\vartheta)\} \quad \varepsilon(t,\vartheta) = y(t) - \hat{y}(t,\vartheta) \tag{2}$$

In case an optimal solution has to be found after N input and output measurements are carried out, $V(\vartheta)$ can be approximated by $V_N(\vartheta)$:

$$V_N(\vartheta) = \frac{1}{N}\sum_{k=1}^{N} 0.5\varepsilon^2(k,\vartheta) \tag{3}$$

Figure 2 gives the optimised exponential relation for five sections in one 330m harvest strip with a large variance in threshability due to different nitrogen applications and slope *(α)* fluctuations. In the first and last section, some data points are laying near to the X and Y-axis respectively because of

the dynamic step responses when the harvester enters and leaves the crop.

Recursive estimation of grain loss curves

As can be seen in Figure 2, a large variance in threshability can be detected in one single crop strip. Therefore, it is preferable to have an online optimal estimation (in accordance with the invention) of the local separation behaviour. This site specific information offers new possibilities for automatic tuning systems in a more direct way compared to the online yield mapping system of Schneider *et al* (1993), since it immediately relates feedrate $u(t)$ with straw walker losses $y(t)$ and provides an extra crop parameter that plays an important role in the evaluation of new crop varieties.

Herein an online optimisation procedure is derived based on a stochastic gradient method. Stochastic approximation minimisation algorithms have been discussed by Krushner and Clark (1978) and have been further worked out within the framework of recursive identification by Ljung and Söderström (1986). The stochastic gradient method can be seen as a stochastic analog of the method of steepest descent for the minimisation of a deterministic function. This method of steepest descent is given by

$$x^{(t+1)} = x^{(t)} - \gamma^{(t)}\left[\frac{d}{dx}V(x)\right]^T\Big|_{x=x^{(t)}} \quad (4)$$

where $x^{(t)}$ denotes the t th iterate and $\gamma^{(t)}$ a chosen positive scalar. Particularly when the iterates are getting close to the minimum, this method is known to be fairly inefficient.

The so-called quasi-Newton methods give distinctly better results and use a modified search direction from the negative gradient direction:

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$$x^{(t+1)} = x^{(t)} - \gamma^{(t)}\left[\frac{d^2}{dx^2}\right]^{-1}\left[\frac{d}{dx}V(x)\right]^T\Big|_{x=x^{(t)}} \tag{5}$$

This iteration will provide convergence in one step to the minimum of $V(x)$, if this function is quadratic in x.

Within the framework of recursive identification the quasi-Newton optimisation scheme can be transformed into following gradient scheme, which could be called a "stochastic Newton algorithm":

$$V(\vartheta) = \mathrm{E}H(\vartheta, e(t)) \tag{6}$$

$$\hat{\vartheta}(t) = \hat{\vartheta}(t-1) + \gamma(t)\left[\bar{V}''\left(\hat{\vartheta}(t-1), e^t\right)\right]^{-1} Q\left(\hat{\vartheta}(t-1), e^t\right) \tag{7}$$

where $\bar{V}''(.)$ denotes the approximate Hessian, $-Q$ (.) is the gradient of $H(x,e)$ with respect to x and e^t indicates that the approximation depends on previous noise values $e^t = e(t), e(t-1), \ldots$ When this scheme is applied on the problem definition of equation (1) and (2), following algorithm is obtained

$$\hat{\vartheta}(t) = \hat{\vartheta}(t-1) + \gamma(t) r^{-1}(t)\psi\left(t, \hat{\vartheta}(t-1)\right)\varepsilon\left(t, \hat{\vartheta}(t-1)\right) \tag{8}$$

where $\psi(t,\vartheta) = \frac{d\hat{y}(t,\vartheta)}{d\vartheta}$ and scalar $r(t)$ corresponds with the instantaneous estimation of Hessian $V''(\vartheta)$. When a loss estimation function (1) has been chosen, $\psi(t,\vartheta)$ will be equal to $\exp(\theta u)u$.

The accuracy of this approximation of the true Hessian plays a particularly important part when the recursive algorithm is operating close to the

minimum. The natural approximation of this Hessian is to introduce the sample means:

$$\frac{d^2}{d\vartheta^2}V(\vartheta)\stackrel{\Delta}{=}\mathrm{E}\{\psi^2(t,\vartheta)\}\approx\frac{1}{t}\sum_{k=1}^{t}\psi^2\left(t,\hat{\vartheta}(t-1)\right)\stackrel{\Delta}{=}r(t) \tag{9}$$

However, the estimation of $r(t)$ in equation (9) puts as much attention on measurements temporally far from t as on previous measurements. Therefore, a weighted estimation of $r(t)$ usually gives better results:

$$r(t)=\sum_{k=1}^{t}\beta(t,k)\psi^2\left(k,\hat{\vartheta}(k-1)\right)+\delta(r)r_0 \tag{10}$$

where r_0 denotes the initial estimation of the Hessian function and weighting coefficients $\beta(t,k)$ and $\delta(t)$ should be chosen such that

$$\sum_{k=1}^{t}\beta(t,k)+\delta(t)=1 \qquad \forall t \tag{11}$$

A standard way to define the weighting coefficients is given by

$$\gamma(t)\equiv\gamma_0 \qquad \delta(t)=\prod_{k=1}^{t}[1-\gamma_0] \qquad \beta(t,k)=\prod_{j=k+1}^{t}[1-\gamma_0] \tag{12}$$

It is easy to verify that this choice of parameters fulfils condition (11). Constant gain parameter γ_0 corresponds to an exponential forgetting factor $\lambda_0\equiv1-\gamma_0$.

Figure 3 shows a preferred but non-limiting practical realisation of this stochastic Newton algorithm. The algorithm is computationally cheap and can easily be implemented in machine software. Three parameters have to

be determined before starting the algorithm. The preferred but non-limiting default values that are used in this study are added between brackets.

1. Gain sequence $\gamma(k)$ is set at a constant value γ_0 (0.2). This parameter immediately determines the tracking capabilities of the algorithm but has also an important influence on the variance on the estimation of parameter $\vartheta(k)$. A high constant gain brings about fast tracking dynamics to follow fluctuations of $\vartheta(k)$, but introduces large fluctuations around the true $\vartheta(k)$, even when the true parameter does not vary in time. It depends on the application purposes and sample frequency whether a high or low gain should be chosen.

2. The initial estimation r_0 (500) of the Hessian function determines the confidence of having an accurate initial estimation of $\vartheta(k)$. A high value of r_0 implies a long term effect of the initial estimation ϑ_0 on the following parameter estimations.

3. Different strategies can be introduced to choose the initial parameter estimation ϑ_0 (8). The last parameter value of a previous harvest run can be used or a parameter estimation of a near by crop strip when the tracking algorithm is connected to a positioning system.

Results and discussion

The algorithm that has been developed in the previous section can be used to track the relation between all combinations of separation and feedrate sensors. Herein, the relation between feedrate and straw walker losses is studied in more detail, since it is immediately related with eg. automatic tuning systems that control the straw walker losses by adapting the feedrate. When the static nonlinear characteristic between both signals can be tracked

online, a ground speed control system can be desired that keeps the straw walker losses at a predefined level. When this knowledge about the instantaneous separation behaviour is not available, more conservative controllers have to be designed, resulting in lower control performances.

In Figure 2, the signals of one 330 m harvest strip are divided into five distinct sections. For each section, an optimal exponential parameter ϑ is calculated based on offline optimisation techniques. Figure 4 shows the results of the recursive algorithm for the same harvest strip. The results of the offline optimisation procedure are added to illustrate the performance of the tracking algorithm. About the same parameters are obtained, but now in an online, recursive way. The zone between 50 and 150 m corresponds to data from an uphill section (+15%). Harvesting uphill reduces the separation capacity of conventional harvesters and as a result, larger coefficients ϑ are obtained. Similar results are found for zones with smaller grain/straw ratios or higher moisture contents.

Site-Specific interpretation of estimated parameter sequence

In case variations of parameter ϑ depends on local field conditions, the same trend should be visible in adjacent strips. Figure 5 shows this type of parameter map for a set of 7 runs that are harvested uphill, parallel to the Y-axis. The correlation with the field slope or machine slope is obvious, illustrating the value of this type of parametric maps for tuning harvesters online, before variations in local processability are actually registered. This field was fertilised with different doses of Nitrogen in strips parallel to the Y-axis. Therefore, the harvester reacts in a slightly different way according to the Nitrogen gift and by this, to its position on the X-axis. A field with a constant Nitrogen application would give even a better correlation of the parameter and slope map.

Although in the foregoing discussion the relationship between feedrate and straw walker losses is described, the method of the invention could equally well be used in comparing feedrate effects on the threshability parameter θ at any of the following parts of a combine harvester:

the separation section, eg. the straw walker or the separator rotor;

the sieves;

the return flow system; or

the cleaning section;

or indeed in parts of other kinds of harvester.

A processability parameter can also be used for predicting the behaviour of the harvesting machine with respect to other effectiveness values such as the proportion of damaged useable crop parts, e.g. broken grain kernels, or a proportion of unwanted material in the useable crop parts, e.g. chaff and straw and particles in the clean grain.

The ability of the method of the invention to optimise the parameter ϑ in an online way offers numerous potential advantages, such as:

the ability to devise a vehicle control system that controls a performance variable of the harvesting machine and that relies on a feedrate set point calculated by an inverted form of Equation (1);

the ability to devise processability-based expert systems, eg. diagnostic systems that are self-executing in a combine harvester; warning system manifested as feedrate or parameter "out of range" values; or information systems such as gradient-related data about likely crop losses.

A further advantage of the methods of the invention is that the processability parameter ϑ can if desired be assessed largely independently of the various sensing subsystems of a harvesting machine equipped for precision farming. In other words the optimised threshability parameter ϑ implicitly takes account of the crop, vehicle and field conditions that give

rise to a particular value of ϑ, without necessarily having to evaluate each individual cause.

CLAIMS

1. A method of substantially continuously optimising a stochastic parameter that characterises the instantaneously prevailing readiness with which a harvesting machine processes crop, including the step of recursively calculating the optimised parameter value in accordance with the following algorithm:

$$\vartheta(t) = f(\vartheta(t-1),\ldots,\vartheta(t-n_\vartheta),\varepsilon(t),\ldots,\varepsilon(t-n_\varepsilon),t) \quad \text{- (A)}$$

wherein

$\vartheta(t)$ is the stochastic parameter value at time t; and

$\varepsilon(t)$ is an error prediction function.

2. A method according to Claim 1 wherein the algorithm (A) has the form:

$$\hat{\vartheta}(t) = \hat{\vartheta}(t-1) + \gamma(t)r^{-1}(t)\psi\left(t,\hat{\vartheta}(t-1)\right)\varepsilon\left(t,\hat{\vartheta}(t-1)\right)$$

wherein

$\gamma(t)$ is a gain term;

$r(t)$ is a scalar approximation of a Hessian $V''(\vartheta)$ in which V is indicative of the harvesting machine load; and

$\psi(t,\vartheta) = \dfrac{d\hat{y}(t,\vartheta)}{d\vartheta}$, in which $\hat{y}(t,\vartheta)$ is an estimation of a value indicative of the effectiveness of said harvesting machine processing said crop.

3. A method according to Claim 2, wherein ;

said crop processing by said harvesting machine comprises separating crop parts from other plant matter;

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V is the voltage output of a transducer that is indicative of the feedrate of crop into the harvesting machine; and/or

$\hat{y}(t,\vartheta)$ is an estimation of useable crop losses in a selected part of the harvesting machine.

4. A method according to Claim 2 or 3, wherein the algorithm (A) includes an estimation of $r(t)$ that is weighted to reduce the influence, on the optimised parameter values, of past measurements of crop feedrate.

5. A method of operating a harvesting machine comprising the steps of:

(i) substantially continuously optimising a stochastic parameter that characterises the instantaneously prevailing readiness with which the harvesting machine processes crop;

(ii) substantially continuously adjusting a performance variable of the harvesting machine in dependence on the instantaneous, optimised value of the said parameter in order to optimise the load of the harvesting machine so as to keep a value indicative of the effectiveness of said harvesting machine below a predetermined value.

6. A method according to Claim 5, wherein:

processing the crop comprises separating useable crop parts from other plant matter;

optimising the load of the harvesting machine comprises optimising the feedrate of crop into the harvesting machine; and

the effectiveness value comprises losses of useable crop parts.

7. A method according to Claim 5 or 6 wherein the step (i) includes carrying out the method steps of any of the Claims 1 to 4.

8. A method according to any of the Claims 5 to 7 wherein the step (ii) of adjusting a performance variable of the harvesting machine occurs in

dependence on the output of an inverted form of a yield loss estimation function:

$$\hat{y}(t,\vartheta) = \exp(\vartheta u(t)) - 1 \qquad \text{- (B)}$$

9. A method of mapping one or more field lots for variations in a stochastic parameter that characterises the instantaneously prevailing readiness with which a harvesting machine processes crop, the method comprising the steps of:

(i) operating a harvesting machine to harvest crop in a said field lot;

(ii) simultaneously measuring the machine load and the machine effectiveness and determining the position of the machine in the field lot;

(iii) storing data indicative of the position of the harvesting machine at time t;

(iv) using the measured machine load and machine effectiveness data in an optimisation of the said parameter; and

(v) mapping the optimised parameter values obtained from step (iii) so as to produce a parameter map of the field lot.

10. A method according to Claim 9 wherein the step (iv) includes carrying out an optimisation according to any of the Claims 1 to 4.

11. A method of operating a harvesting machine comprising the steps of:

(i) substantially continuously optimising a stochastic parameter that characterises the instantaneously prevailing readiness with which the harvesting machine separates useable crop parts from other plant matter;

(ii) sending a display signal, that is indicative of the instantaneous parameter value, to a display device.

12. A method according to Claim 11 wherein the step (i) of optimising a

stochastic parameter includes carrying out the method of any of the Claims 1 to 4.

13. A method according to Claim 11 or Claim 12 wherein the display signal indicates an abnormal parameter value.

14. Methods according to any preceding claim wherein the harvesting machine is a combine harvester and the crop is a grain-bearing plant.

15. Methods according to Claim 3 or any other Claim referring thereto, wherein the said selected part of the harvesting machine is selected from:

the straw walkers;
the rotary separator;
the sieves;
the grain elevator
the return flow system; or
the cleaning section;

of a combine harvester.

16. Methods generally as herein described with reference to and/or as illustrated in the accompanying figures.

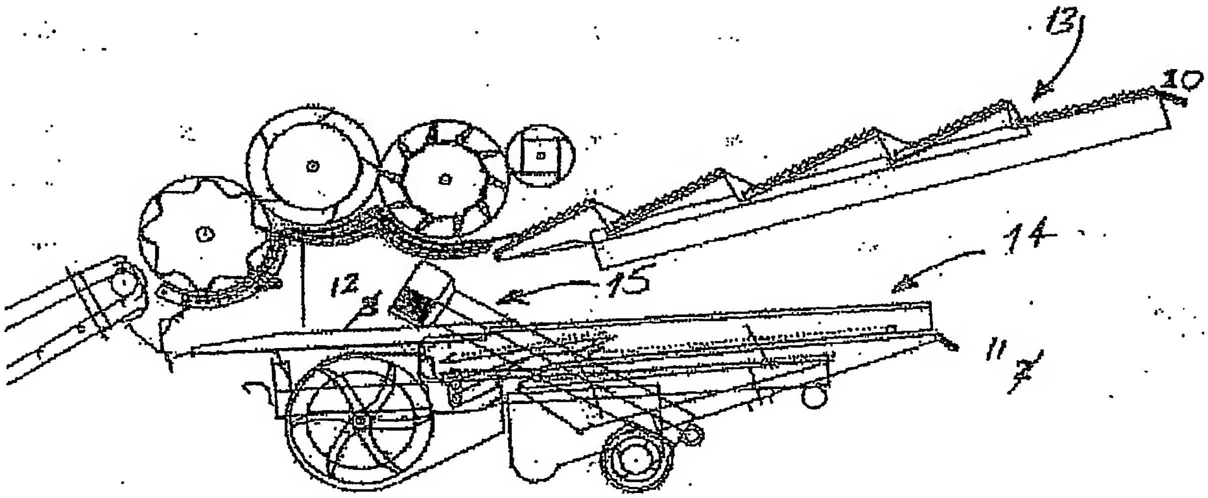


Figure 1

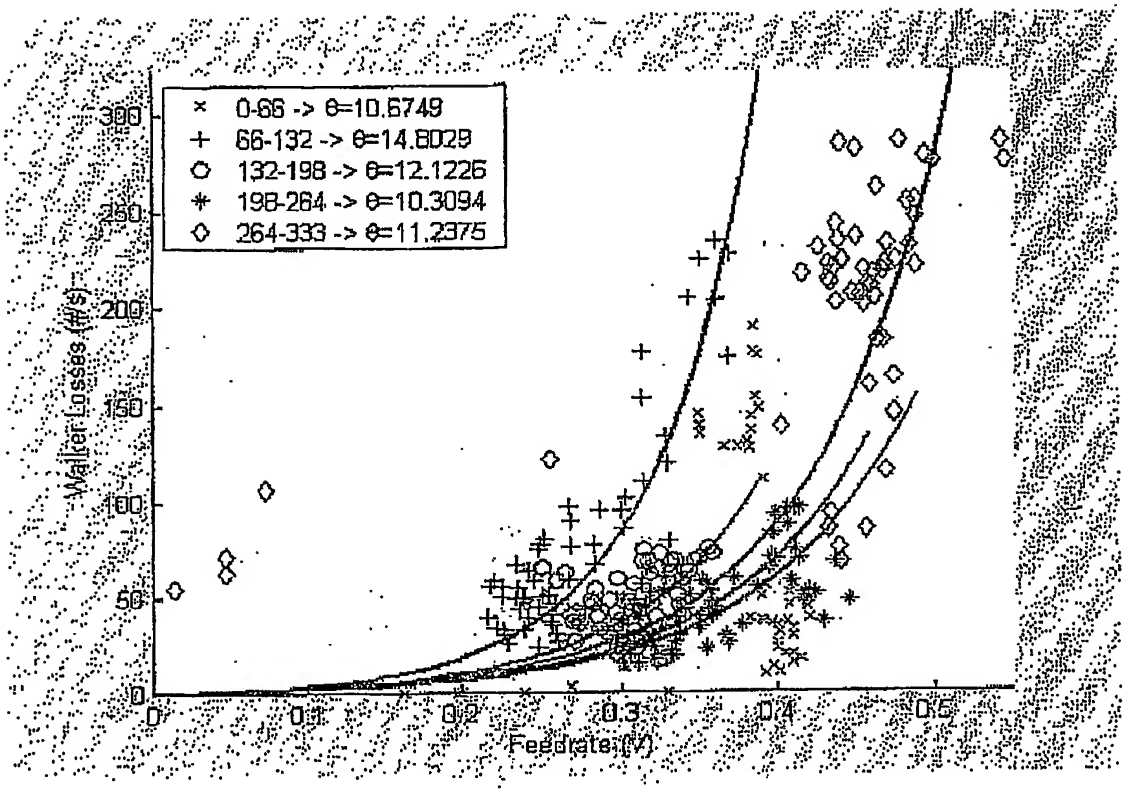
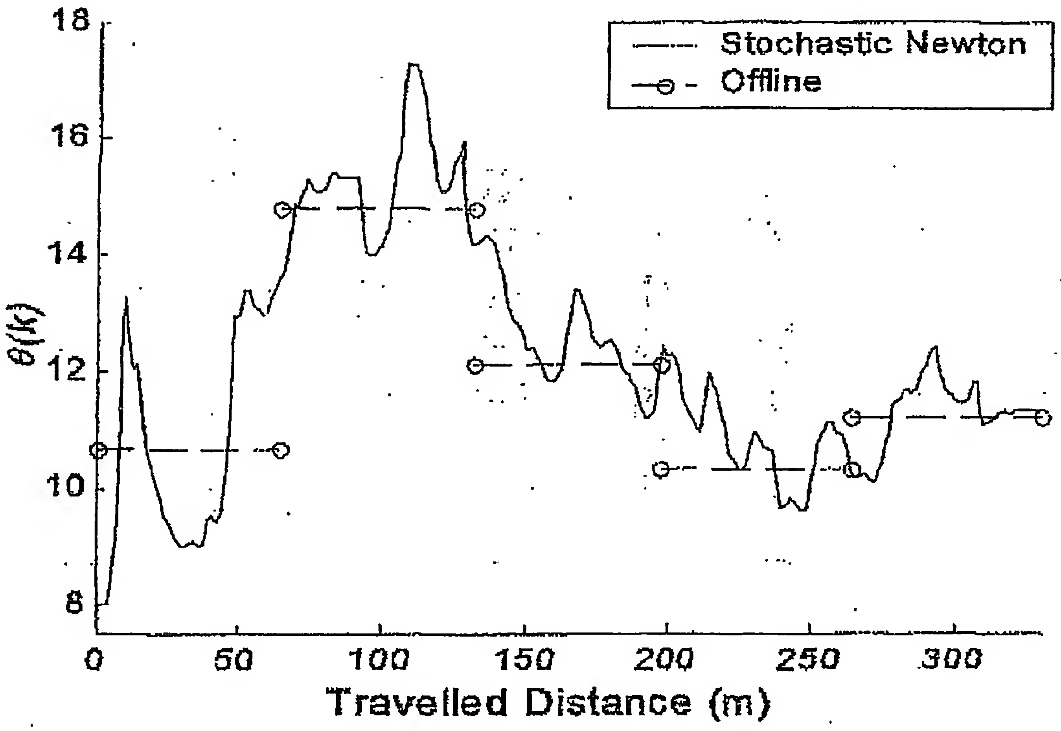

0-66 -> θ=10.6749
66-132 -> θ=14.8029
132-198 -> θ=12.1226
198-264 -> θ=10.3094
264-333 -> θ=11.2375
Walker Losses (#/s)
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
Feedrate (V)

Figure 2

```
r(0)=r0;
θ(0)=θ0;
k=1;
while (k<N),
  ψ(k)=u(k)*exp[u(k)*θ(k-1)];
  ε(k)=y(k)-exp[u(k)*θ(k-1)]+1;
  r(k)=r(k-1)+γ0*[ψ²(k)-r(k-1)];
  θ(k)=θ(k-1)+γ0*ψ(k)*ε(k)/r(k);
  k++;
end;
```

Figure 3



Stochastic Newton
Offline
18
16
14
12
10
8
θ(k)
0
50
100
150
200
250
300
Travelled Distance (m)

Figure 4

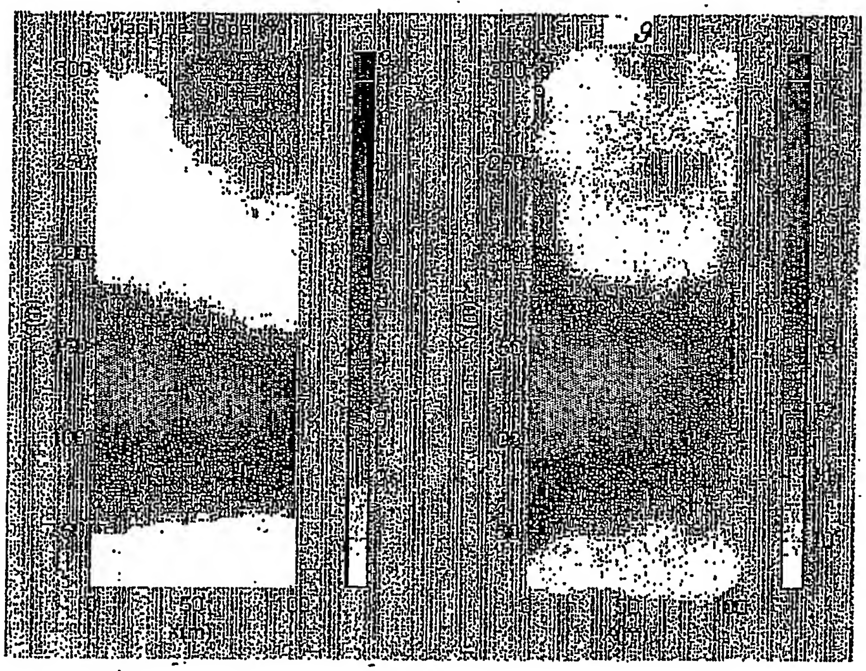


Figure 5